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Techniques for Sampling and Analyzing the Marine Macrobenthos

Corvallis Environmental Research Lab, Oreg

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TECHNIQUES FOR SAMPLING AND ANALYZING THE MARINE MACROBENTHOS

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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory.

The primary mission of the Corvallis laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report describes sampling designs, collection methods, laboratory techniques, and data analysis procedures for investigation of the response of marine macrofaunal benthic communities to pollutional stress. It is part of a series of reports on sampling guidelines for benthic, zooplankton, phytoplankton, demersal, and intertidal marine assemblages.

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Corvallis Environmental
Research Laboratory

ABSTRACT

This report presents guidelines for the quantitative assessment of the effects of marine pollution on benthic community structure and population dynamics. The sampling design addresses the number and location of stations, survey frequency, sampling gear, replication of samples, screening and preservation of biological samples, and the collection of abiotic data. Recommendations are given for the sorting, identification, enumeration, and weighing of benthic specimens. The section on data analysis suggests indices for detecting changes in species composition, density, dispersion, diversit, richness, dominance, and spatial-temporal faunal homogeneity.

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SECTION I
CONCLUSIONS

Alteration of the structure of benthic macrofaunal communities can indicate the effects of pollution and natural stress on marine ecosystems. The benthic survey techniques recommended here are not meant to be standard methods, but rather guidelines to the kind of investigation necessary to obtain meaningful results.

Survey designs must realistically reflect the time and resources required for accurate field and laboratory processing of the samples. A design which specifies as few as ten stations will necessitate a major sampling effort. A fixed station grid or transect is recommended for surveys of ocean disposal sites and point sources of pollutants. The null hypothesis to be tested assumes no significant differences in biotic conditions between control and presumably stressed sites. Substantial environmental heterogeneity would require stratified sampling.

Five 0.1 m^2 Smith-McIntyre grabs should be taken at each station and cruises should be conducted at least once every three months. The minimum screen size must not exceed 1.0 mm. Bottom water temperature, salinity, and dissolved oxygen, and pollutant concentrations in the sediments, water and biota should be monitored at each station. A core from all grabs must be preserved for analysis of sediment size distribution.

All specimens belonging to the major macrofaunal taxa (amphipods, polychaetes, molluscs, echinoderms, etc.) must be identified to the species level, enumerated, and weighed. Wet biomass estimates should be converted to ashfree dry weights. Accurate species identifications are a vital part of the benthic survey. They should be conducted by experienced biologists with the aid of the best available keys and reference collections prepared by or in consultation with expert taxonomists. It

is often appropriate to make special observations on the biology of selected species, e.g., size distribution, disease frequency, or reproductive success.

No single aspect of population or community structure can serve as an unequivocal index of biotic response to stress. Possible changes in species composition, density, dispersion, diversity, richness, dominance, and spatial-temporal faunal homogeneity should always be examined. Patterns of these structural parameters should be compared with each other and with other aspects of the biology of the benthos.

Biotic response to human perturbation is difficult to predict. For example, diversity and density do not always decrease in altered marine environments. Also, slight modificatons of benthic community structure are not necessarily deleterious. Beyond statistical significance, interpretation of the ecological importance of biotic change must ultimately lie in the judgment of experienced ecologists.

SECTION II
INTRODUCTION

This report presents quantitative methods for assessing the condition of benthic communities. The species composition, density, and structure of the macrofaunal benthos are good indicators of the effects of stress on marine ecosystems. This is especially true for the impact of materials which accumulate on the bottom and affect the biota directly through toxic action or indirectly through altered sediment characteristics. Since dredge spoils,sewage sludges, and some other materials dumped at sea fall into this category, benthic surveys may often be required to provide guidance for EPA's Ocean Disposal Permit Program. The methods described here are also appropriate for research on undisturbed benthic habitats.

There are no standard techniques for benthic sampling and data analysis. Ecologists use different collecting gears, sieve sizes, mathematical indices, etc., according to the unique requirements of individual investigations. The techniques recommended here will generally provide the data necessary for a comparative, quantitative analysis of the subtidal benthos of estuarine and coastal waters. Although these methods are not absolute requirements, alteration of the survey design should result in at least an equally rigorous investigation. The thorough review of benthic survey methods edited by Holme and McIntyre (1971) provides additional information on sampling designs.

SECTION III
SAMPLING

LOCATION AND NUMBER OF STATIONS

The location and number of stations must be determined for each survey according to:

1. Objectives of the survey

2. Size and configuration of the survey area.

3. Environmental conditions at the site, especially spatial changes in sediment characteristics, depth, salinity, biotic assemblages, and pollutant concentrations.

4. Physical and chemical characteristics of the material to be dumped or dredged, and predictions of dispersion patterns.

5. Need for "control" samples taken at comparable habitats which will not be exposed to the same degree or kind of stress.

6. Human and material resources of the survey.

Sufficient information will seldom be initially available for all of these factors. A preliminary examination of the biological, chemical, and physical characteristics of the survey area may prevent wasted effort. The presurvey need only consist of qualitative sampling or direct observations of the bottom.

The number of stations is limited by the time required for post-cruise processing of biological samples. Following the sampling design

presented below, a scientist familiar with the species at the site will require at least two weeks to sort, identify, enumerate, and weigh specimens taken at a single station. It is desirable to collect more samples than may be needed, but stations which are critical to the survey should be occupied first. It is not necessary to make benthos collections at every water quality station. Survey designs which specify more than ten biological stations are very expensive both in field costs (especially at offshore sites) and laboratory effort.

Locate stations at offshore dumping grounds along at least two transects crossing one another at the center of the site and extending beyond its perimeter. One transect should be parallel to the predicted direction of net motion of dumped materials on the seabed. Stations must be located at the center, margin, and beyond the margin of the site. The latter serve as "controls" but a reference station(s) further away may also be necessary. It probably will not be possible to find a control habitat which differs from the survey site only in the absence of dredging or dumping activities. However, the reference stations can serve as controls in the sense that the benthos may not be affected to the same extent as within the dump or dredge site.

Location of stations along transects lends itself to a gradient analysis of the effects of stress. Random location of stations would permit a description of the biota of the entire site, but the number of stations necessary for such a design is usually prohibitive.

If substantial natural changes in environmental conditions occur in the survey area, it is necessary to stratify sampling by placing stations in each habitat type. For example, if both coarse sand and mud bottoms are found at a dump site, stations (including controls) must be placed in areas of each sediment type.

Benthic surveys of dredged channels must include two or more transects perpendicular to the channel. Locate at least three stations along each transect at the center, margin and outside of the channel. In estuaries and bays the location of transects should reflect salinity gradients. Relatively minor changes in depth can be signficant if the survey area includes a portion of the intertidal zone.

SAMPLING GEAR

A variety of benthic grabs have been used for quantitative sampling (Holme, 1971). The "bite" area is essentially constant, but the depth of penetration varies with sediment characteristics and must be recorded for each sample. The Smith-McIntyre (1954) grab is recommended for use in estuaries and on the continential shelf. It is mechanically reliable and samples a reasonably large area (0.1 m^2). Screens on the back of the jaws can be removed to permit direct observation of the surface of the sediments. Cores for meiofaunal, chemical, and geological analyses can be removed from the undisturbed sample. Additional weights can be added to the Smith-Mcintyre grab to sample sediments that are difficult to penetrate. Other grabs, especially the van Veen and box corer, can also be used for quantitative surveys. Anchor dredges such as the one used by Sanders, Hessler, and Hampson (1965) can provide large benthic samples from the deep sea.

REPLICATION

The number of replicate grabs per station depends on the community and population characteristics of interest. Accurate estimates of the density of a rare species with a patchy distribution might require hundreds of samples. The design of benthic surveys at dredging and dumping sites should provide the data necessary for an analysis of the spatial-temporal distribution of the more common species and the biotic

assemblage as a whole. A single sample per station will not permit a statistical evaluations of variations. McIntyre's (1971) recommendation of five grabs per station should be followed when possible. The number of replicates should never be less than three. If necessary reduce the number of stations so that an adequate number of grabs can be taken at each.

Stations should be sampling areas (perhaps 0.25 km square) rather than discrete points and random sampling should be attempted within each "station." This minimizes the possibility that due to patchiness or other causes the collections might not be representative of true variations in biological conditions.

SURVEY FREQUENCY

Because major seasonal changes occur in the structure and function of benthic assemblages, long-term monitoring programs should include surveys at no more than three-month intervals. Quarterly surveys can be designed so that samples are processed and analyzed before the next cruise. Baseline studies of biological conditions should continue for at least one annual cycle. An analysis of annual variations will require two or more years of sampling.

COLLECTION OF GRAB SAMPLES

A power winch (preferably hydraulic) and a davit, boom, or A-frame arrangement are essential for lifting a weighted Smith-McIntyre grab onto the deck. After the grab is placed on a waist-high stand, remove the screen on one side to see if an adequate sample has been taken. Reject samples which are very shallow or which lost sediments during retrieval. Record the maximum depth of the bite and take cores (approximately 4 cm in diameter) from <u>each</u> sample for sediment size distribution and chemical analyses. A core may be taken for the study of meiofauna.

Record the color, texture and obvious vertical stratification of the sediments and section the cores if they cannot be preserved intact. Note the presence of tubes, burrows, and epibenthic organisms. If the stand is equipped with a large funnel, the remainder of the sample can easily be dropped into a bucket for storage until the sediments can be screened. Record the volume of sediments in the bucket as a second estimate of the size of the sample.

SCREENING AND PRESERVATION

Sieving sediments and removing organisms from the screens are critical parts of the benthic survey and should be done with great care. The sieve mesh size must not exceed 1.0 mm. A good sieve can be constructed by nailing a 40x40 cm screen to the bottom of a 10 cm deep wooden frame equipped with sturdy handles. The screen should be sealed to the wood with silicone rubber to prevent animals from crawling into the crevices at the edges. Filtered seawater can be used to wash the sediments through the screen. Samples can be washed more efficiently and less destructively by dipping and shaking the bottom of the sieve in a tub of seawater. Remove the larger organisms with a pair of forceps and then wash the remaining sediments (sometimes more than a liter) into one corner of the screen and spoon them into a separate jar. Fix the organisms and sediment residue in a 10% formalin-seawater solution and transfer them after a week to 70% ETOH-5% glycerine for permanent storage. A label giving appropriate station and sample data written in indelible ink on high quality rag paper must be placed in each jar. Specimens to be used for chemical analyses must be frozen if they cannot be analyzed immediately.

ABIOTIC DATA

The water depth and bottom water temperature, salinity, and dissolved

oxygen must be recorded at each station. The grain size distribution of the sediment samples is determined for sand by sieving through a Wentworth scale screen series and for the silt-clay fraction by the pipette method (Buchanan, 1971). Other chemical and physical analyses of the water, sediments, and biota will usually be necessary to establish correlations between biotic and abiotic conditions.

SECTION IV
SAMPLE PROCESSSING

SORTING AND SPECIES IDENTIFICATION

Specimens should first be sorted to higher phylogenetic levels (order or above). It may not be practical to identify specimens from all phylogenetic groups to the species level. For example, meiobenthic nematodes and copepods are occasionally retained on 1.0 mm screens and their complete identification may not justify the necessary taxonomic effort. However, it is essential to identify the species of the most important taxa, i.e., those higher groups (amphipods, polychaetes, pelecypods, gastropods, echinoderms, etc.) which dominate the macrobenthos in numbers of species and individuals, biomass, or functional significance.

Accurate species identifications are a vital part of a macrobenthos survey. The paucity of trained taxonomists will force most projects to develop their own classification capability. This is a major task and will require weeks, perhaps months before a novice can confidently identify an amphipod or polychaete to the species level. Throughout the project the same person should identify all specimens from each phylogenetic group.

The best available keys must be acquired before species identifications are attempted. A reference collection of the major taxa in the samples should be obtained from or constructed with the aid of expert taxonomists. The reference specimens must be keyed out to confirm the classifier's familiarity with the appropriate taxonomic characters. Comprehensive keys do not exist for all taxa from all areas. If a clearly distinct species cannot be identified beyond the familial or generic level, it can simply be given a number, e.g. Nereid 1 or Ampelisca 2. If the species is common, it should be sent to a taxonomist for identification.

ENUMERATION

Specimens of all except colonial species should be counted individually. Record colonial bryozoans, hydroids, etc. as present or absent. Count fragments only when they clearly represent a single organism. Place specimens of each species in separate vials labeled with the species name and sample number. If possible store the collections permanently and never discard them before final action is taken on a permit application.

BIOMASS

Determine the wet weight after blotting for each species in each sample to the nearest 0.1 mg. The wet weight should include hard parts of the body, but not tubes and protective coverings not attached to the body. Report biomass as ash-free dry weight, estimated from the wet weight data by appropriate species-specific conversion factors. These factors can sometimes be found in the literature or can be determined by the relation of wet weight to the difference between the weight after drying at 105 C for several hours and the weight after incineration at 500 C. The conversion factors may change seasonally due to growth and reproductive cycles.

OTHER OBSERVATIONS

Information beyond the biomass, number of individuals and identity of each species should be recorded when preliminary results indicate a need for more detailed study.

Biological Tissue Analysis

The concentration of chemical pollutants in biological tissues should be determined when there is evidence of direct toxic action or

bioaccumulation and magnification through the food chain. Special collecting methods may be necessary because grab samples do not consistently provide the quantity of the same species required for some chemical analyses. It is best to determine the concentrations in specific organs of individual specimens, but it may be necessary to pool whole bodies of all specimens of the same phylogenetic group.

Size Distribution

The length, width or diameter of each specimen of a particular species can be measured to document differences in size frequency distribution. The precision of measurement should not be less than 1/20 of the size range of the collection. An ocular micrometer or set of dividers and rule are the best measurement tools for most benthic organisms.

Reproductive Condition

Reproductive success and seasonal cycles can be described by the presence of external egg masses, ripe gonads, or other criteria of reproductive condition. The size, sex, and if possible, stage of sexual maturity must also be recorded for each specimen.

Disease

The type and incidence of all diseases and abnormalities must be noted. Affected specimens should be sent to an invertebrate pathologist for examination.

Meiobenthos

The 1.0 mm screen was recommended for the study of the macrobenthos because it will usually retain a sufficient diversity and quantity of

organisms to make spatial-temporal comparisons of biological conditions. It this is not true, a finer screen (0.25 or 0.50 mm) must be used to collect smaller organisms. The taxonomy of the meiobenthos is less well known than that of the macrobenthos; most of the benthos passes through 1.0 mm screen and enumeration is consequently more difficult; and the finer screens retain a much larger fraction of the sediments. Except for these problems, study of the meiobenthos would be required routinely. The meiobenthos cores from the grab samples can be screened independently or, for a larger sample, a fine screen can be stacked below the 1.0 mm screen during the initial sieving. The meiobenthos should be processed in the same manner as the macrobenthos. The data should be analyzed separately and perhaps later pooled with information on the macrobenthos.

SECTION V
DATA ANALYSIS

Macrobenthos analysis can determine if ecologically important differences exist between the biota of control and dump sites. Causal relationships can be indicated through correlations between biotic and abiotic factors. Bio-mathematical indices and statistical tests are part of the analysis, but the interpretation of benthic data must include the judgement of experienced ecologists.

Every aspect of the biology of a species can be affected by stress. The emphasis of this survey design is on species composition, abundance, and community structure. The scientific literature must be reviewed for additional information that will permit a more complete understanding of observed or predicted biotic responses to dredging and dumping activities.

PRESENTATION OF DATA

Numeric and biomass densities should be given in separate tables for the collections at each station (Table 1). These tables give information at the population (single species) and community (multi-species) levels. Discussion should begin with the characteristics of the ecologically and economically important populations. Equations for bio-mathematical indices (species diversity, faunal affinity, etc.) are given below, and general statistical formulae (standard deviation, analysis of variance, etc.) can be found in most statistics texts.

POPULATION CHARACTERISTICS

Species Composition

The presence or absence of species is the most basic result of a

Table 1. Recommended format for presenting numeric density data from the five grabs taken at each station. A similar table must also be given for the biomass data

Species	Grab Number 1	2	3	4	5	Total	Mean	Standard Deviation	Coefficient of Dispersion	95 Percent Confidence Limits of Mean	Numeric Rank	Percent of Total	Cumulative Percent of Total
Pseudunciola olbiquua	160	145	33	112	67	517	103.4	53.1	27.27	37.5-169.3	1	57.3	57.3
Spiophanes bombyx	82	74	56	73	38	323	64.6	17.6	4.80	42.8-86.4	2	35.8	93.1
Trichophoxus epistomus	11	4	15	9	14	53	10.6	4.4	1.83	5.1-16.1	3	5.9	99.0
Acanthohaustorious millsi	0	3	0	2	0	5	1.0	1.4	1.96	0-2.7	4	0.6	99.6
Byblis serratus	3	0	0	1	1	5	1.0	1.2	1.44	0-2.5	4	0.6	100.2
Total	256	226	104	197	120	903	180.6	66.2	24.27	98.4-262.8			
Number of Species	4	4	3	5	4	5	4.0	0.7		3.1-4.9			
Species Diversity (H')	0.367	0.338	0.424	0.392	0.426	0.395	0.389	0.04		0.339-0.439			
Dominance (Complement of Simpson's Index)	0.507	0.483	0.594	0.545	0.579	0.541	0.542	0.05					

biotic survey and can be very informative, especially for organisms known to be stress tolerant or intolerant. The literature on marine bioassays and the results of previous benthic investigations can be helpful in the identification of indicator species. The distribution of the benthos at existing dump sites is sometimes a consistent pattern of presence of many species at the periphery and absence of most at the center of the site.

Abundance

Dominant species are often ubiquitous and differences in their densities (both biomass and number of individuals) must be examined quantitatively. The mean density and its standard deviation and confidence limits (Table 1) can be used to describe spatial-temporal changes in abundance. The confidence limits of the density of individual species are usually very large because of patchiness and sampling error. Increasing the number of replicate samples from 5 to 20 does not greatly improve the estimates of mean density (McIntyre, 1971).

The Coefficient of Dispersion (variance: mean ratio) indicates whether the distribution of a species on the bottom is random (CD=1), clumped (CD>1), or even (CD<1) (Greig-Smith, 1964). Spatial distribution patterns can be important in determining interspecific and environmental relationships. Also, when the pattern is random or clumped, the assumptions inherent in analysis of variance may not be valid unless the data are transformed. McIntyre (1971) recommended a square root transformation $(x + 0.375)^{1/2}$ for random patterns, and a logarithmic transformation $(\log_{10}(x + 1))$ for clumped distributions. Nonparametric statistics can also be used for comparing mean densities when analysis of variance is not possible.

Biological Tissue Analysis

Spatial-temporal changes in the concentration of pollutants in biological tissues should be correlated through regression analysis with concentrations in the water, sediment, and dumped materials. Some data is available in the literature on threshold tissue concentrations for deleterious effects of heavy metals, pesticides, etc. Knowledge of feeding mechanisms and trophic position is important in analyzing the accumulation and magnification of pollutants. Through tissue analysis it may be possible to relate ecological alterations to a specific component of dumped materials. In turn, this information would permit modification rather than cessation of dumping practices.

Size Frequency Distribution

Size frequency distribution can document the absence of a particular size class (due perhaps to the failure of a year class in a stressed environment) or establish seasonal growth cycles and rates. Histograms provide convincing evidence of major differences in size distributions and chi-square tests can assess statistical significance in less obvious instances.

Reproductive Condition

Chronic exposure of the benthos to sublethal pollutant concentrations may block reproductive activity. Spatial differences in the frequency of mature females with egg masses (or other criteria of reproductive success) must be reported. Reproductive seasons can be described by plotting percent ovigerous females against time. Information on growth and reproductive cycles is helpful in selecting the best time of the year for dredging or dumping.

Disease

The statistical significances of changes in disease incidence can be tested by chi-square. Diseased specimens should be examined and described by an invertebrate pathologist. The size frequency distribution of afflicted specimens may indicate differences in exposure or susceptibility to stress.

Fisheries

The appearance of any life stage of commercial species in macrobenthic collections must be emphasized. The abundance, spatial distribution, size frequency, local fishery catches, and other pertinent data should be used to assess the existing or potential significance of the area as a nursey or fishing ground. The impact of dredging or dumping on transient fishery stocks and those which cannot be sampled effectively by grabs or other benthic gear must be considered.

Other Population Characteristics

Other information from field observations and the literature about the life history of the most abundant species should be summarized. Data on normal environmental requirements (temperature, salinity, sediment preference, etc.) are important. If they are narrow, will a slight perturbation be disruptive? Could the species be introduced to a new habitat via dredge spoils and compete with the endemic fauna? At dump sites the mode of association with the substrate (tube dwelling, burrower, attached or motile epifauna, etc.) may determine the consequences of burial by dredge spoils. The literature may indicate which species dominate the flow of energy in benthic systems. If nothing is known about the susceptibility of key species to stress, appropriate bioassays should be conducted for the materials to be dumped (Environmental Protection Agency/Corps of Engineers, 1977).

COMMUNITY CHARACTERISTICS

Changes in community structure must be analyzed on the basis of both number of individuals and biomass. Abundance, species diversity, and faunal homogeneity indices should be calculated for all taxa combined and separately for the major phylogenetic groups (Amphipoda, Polychaeta, etc.) in each survey.

Abundance

Abundance at multispecies levels should be reported as the number of individuals and biomass in each sample and in the pooled samples at each station (Table 1). The density of taxonomically and trophically related groups of species (e.g., haustoriid amphipods) may be more informative than that of all species in the collection. Transformations and statistical comparisons between stations are the same as given in section IV for population density.

Species Diversity

Species diversity is a function of the number of species (richness) and the distribution of individuals among the species (Lloyd and Ghelardi, 1964). This is a broad ecological concept and no single diversity index can be accepted as a unequivocal mathematical definition. The three indices recommended here are sensitive to changes in different aspects of community structure. Their interpretation as indicators of multispecies response to stress requires very careful consideration of the theoretical significance of the indices.

Richness can be expressed as the number of species (S) collected per unit effort or area. Obviously this is not an estimate of the total number of species in the community and it is valid only for comparative

study. Constant sampling effort can usually be incorporated into survey designs and S's for different samples can be directly compared. If effort varies, Hurlbert's (1971) equation can be used to estimate the number of species that would have been present if effort had been constant (S_{CE}):

$$S_{CE}=S_0 - \sum_{i=1}^{S_0} \log^{-1}\{[\log(N_0-n_i)!-\log(N_0-n_i-N_{CE})!]-[\log N_0!-\log(N_0-N_{CE})!]\}$$

$$N_{CE}=N_0(E_{CE}/E_0)$$

where: S_{CE} and N_{CE} are the number of species and individuals, respectively, for constant effort.

S_0 and N_0 are the number of species and individuals, respectively, in the original sample.

n_i is the number of individuals of the i^{th} species.

E_{CE} and E_0 are the constant and original sampling efforts. For all samples, $E_{CE} \leq E_0$.

The most important feature of the pattern of distribution of individuals among species that determines "effective" diversity is the extent to which the assemblage is dominated by the abundant species. Fewer species will appear per unit number of individuals in samples from communities in which dominance concentration is relatively high. Dominance concentration can be determined by Simpson's (1949) index (S.I.). S.I. is not greatly dependent on sample size and it is not necessary to adjust to constant effort before calculating the index.

$$S.I. = \sum_{i=1}^{S_0} \frac{n_i(n_i-1)}{N(N-1)}$$

For index values to be postively related to diversity they can be expressed as the complement of S.I. (McIntosh, 1964).

To many ecologists both richness and the species frequency distribution are integrated in a single concept of diversity. The Shannon-Weaver information-theoretical measure of mean species diversity per individual (H') is sensitive to both components of diversity and is a very popular index of "overall" diversity (Pielou, 1970).

$$H' = 1/n \left(N_0 \log N_0 - \sum_{i=1}^{S_0} n_i \log n_i\right)$$

The tables of Lloyd, Zar, and Karr (1968) facilitate the calculation of this index if a computer program is not available.

Diversity patterns have sometimes been misrepresented as comprehensive indicators of the "health" of aquatic ecosystems. Obviously no single index value could summarize all aspects of community structure. A basic limitation to diversity indices is that they are not sensitive to changes in species composition. However, it would be equally erroneous to dismiss species diversity as having no application in pollution biology. Such fundamental ecological concepts as dominance and the number of niches (richness) are certainly pertinent.

Faunal Homogeneity

A simple percent dissimilarity index can document spatial-temporal faunal homogeneity between stations. In Table 1 the Percent of Total column gives the percent each species contributes to the total number of individuals or biomass collected in all samples at each station [$100(n_i/N)$]. A percent dissimilarity index is calculated for all pairs of stations as

the complement of the sum of the minimum value of n_i/N for all species common to the two stations. Index value range from 1.0 when the collections have no species in common, to 0.0 when all species are common and the distribution of individuals is the same on a percentage basis.

An example of the calculation of the dissimilarity index, matrix, and dendrogram is given in Table 2. The dissimilarity index values for all possible pairs of the five hypothetical collections (A-E) are calculated and presented in the original dissimilarity matrix. The collection pair with the lowest dissimilarity index (B and D) is then combined and a second matrix constructed treating BD as a single collection. The dissimilarity between BD and other collections, e.g., A, is the mean dissimilarity in the original matrix between the collections in the combined group and A, i.e., B-A = .80, D-A = .91, BD-A = (.80 + .91)/2 = .86. This procedure is repeated until all collections are combined in a single group. The results are presented in a dendogram which shows the hierarchial relationships between collection groups (Table 2). In this example, two collection clusters with high intra-group faunal homogeneity are evident (B-D and A-C-E). Identification of clusters in dendrograms is subjective and may not always be as straightforward as in Table 2. If all collections are made in areas of similar biotic conditions, attempts to discriminate more than one cluster may be misleading. If collections are made along a continuous gradient, well-defined clusters may not be apparent. However, this site clustering technique may often be useful in describing quantitative differences in faunal homogeneity between natural and disrupted benthic assemblages. Thorough reviews of numerical classification have been made by Clifford and Stephenson (1975) and Boesch (1977).

Other Community Characteristics

The degree of similarity in the distribution of species pairs can be analyzed by the same index given above for comparing station pairs. Clustering techniques can then be used to identify groups of species

Table 2. Example of the calculation of the dissimilarity index, matrix, and dendrogram.

Species	Collection A		B		C		D		E	
	n_i	n_i/N	n_i	n_i/N	n_i	n_i/N	n_i	n_i/N	n_i	n_i/N
1	110	.69	10	.11	46	.51	5	.04	60	.38
2	42	.26	4	.04	30	.33	0	.00	80	.51
3	0	.00	30	.33	5	.05	57	.50	14	.09
4	8	.05	48	.52	10	.11	52	.46	2	.01
Total	160	1.00	92	1.00	91	1.00	114	1.00	156	.99

Dissimilarity Index (A-B) = 1-(.11 +.04 +.00 +.05) = 0.80
Index values for all other collection pairs are given in the original dissimilarity matrix below.

Dissimilarity Matrices

I. Original

	A	B	C	D
B	.80			
C	.18	.69		
D	.91	.17	.80	
E	.35	.75	.23	.86

II. BD Combined

	A	BD	C
BD	.86		
C	.18	.75	
E	.35	.80	.23

III. Group AC Formed

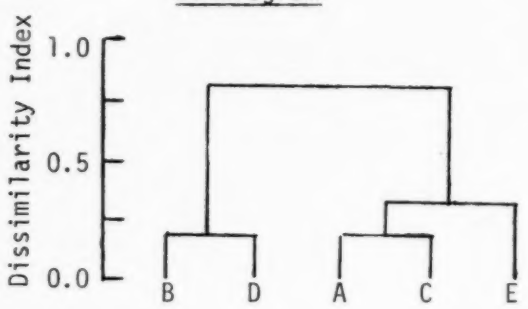
	AC	BD
BD	.80	
E	.29	.80

IV. Group ACE Formed

	ACE
BD	.80

V. Group ABCDE Formed

Dendrogram



which have similar distribution patterns. The appearance or disappearance of species assemblages in response to ecological alterations could be investigated through such techniques. Boesch (1973) gave a good example of the application of this type of classifactory analysis to macrobenthic communities.

If sufficient information exists on the feeding mechanisms, trophic levels or habitat preferences of individual species, it would be important to describe any changes that occur in the dominant patterns at the community level. Species diversity and other indices might be calculated for the infauna, detritus feeders, or some other assemblage defined by ecological similarity and interaction.

Abnormal seasonal fluctations and even longer-term trends towards deterioration can be detected through community structure analysis (Warriner and Brehmer, 1966; McErlean et al., 1973). Data on temporal changes are especially important in baseline surveys because of the need to discriminate between natural temporal variations and those caused by chronic exposure to stress.

SECTION VI
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